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TPF Mirror Technology Assessment

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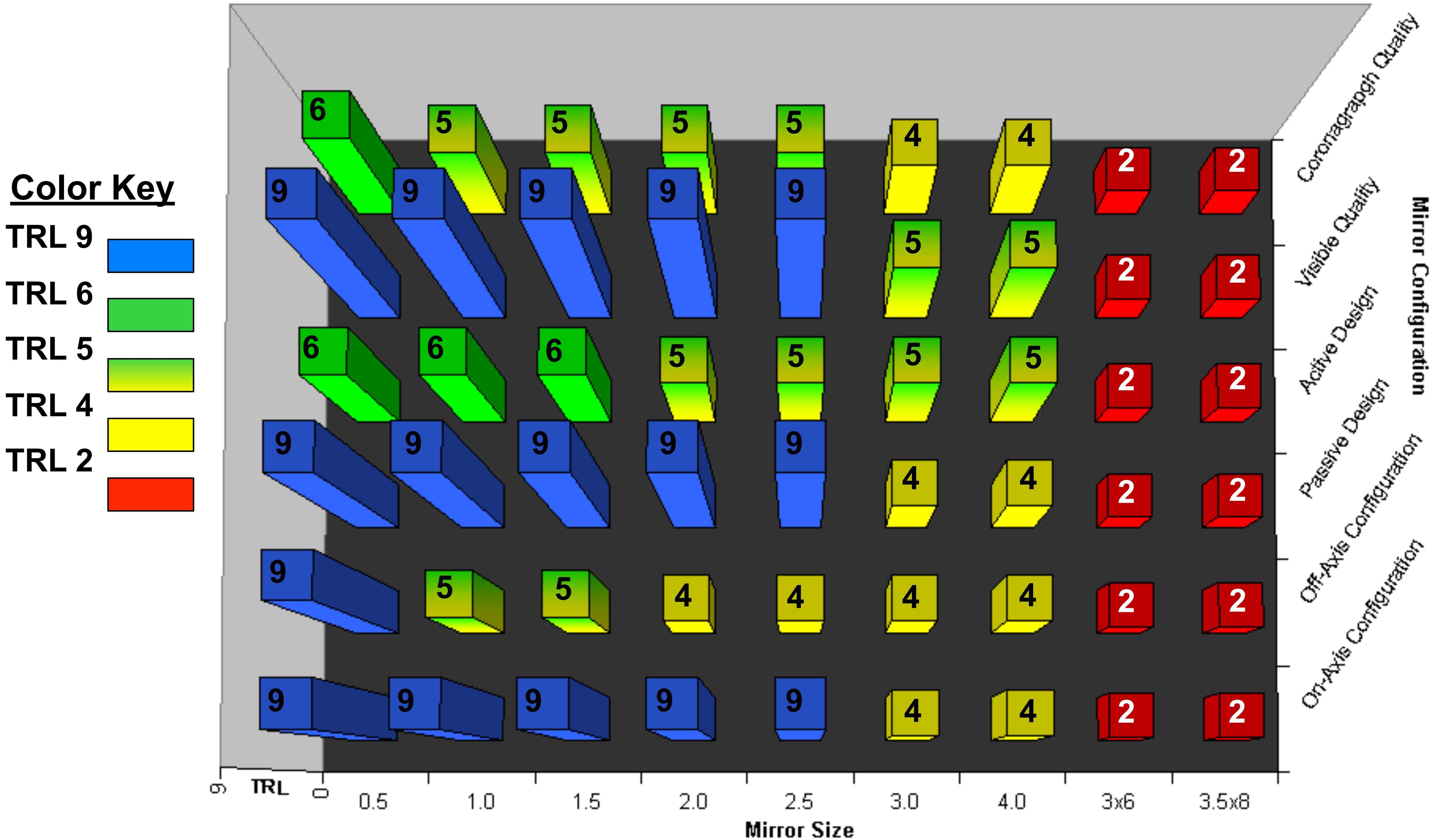
ITT Space Systems Division

TRL Assessment Summary by Feature



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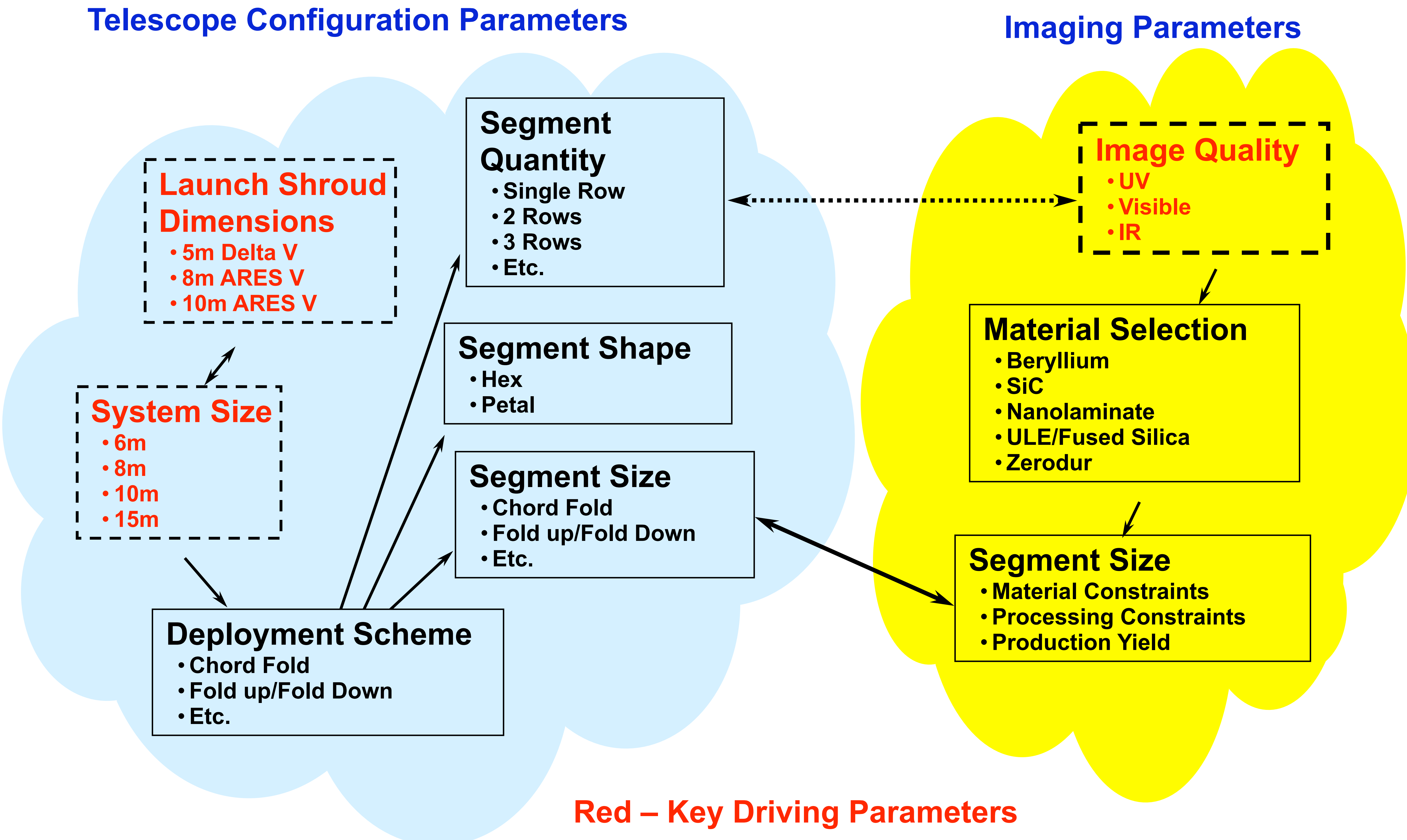
Primary Mirror Parameter Interaction



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Facility Break Points have been identified

	2m - 2.5m	2.5m – 3.0m	3.0m – 4.0m	3.5mx8m
ULE® Glass Manufacturing	No issues. Raw glass manufacturing has been demonstrated to 8m diameter at Corning			
Mirror Blank Manufacturing	Facilities in place at Corning	Facilities in place between Corning and ITT	New furnace required	Segmented Blank manufacturing process requires development
Mirror Processing and Coating	Facilities in place	Minor upgrades required for final finishing and test. Coating chamber required.	Some modifications required for finishing and test. Coating chamber required	Major facility upgrades required.
Recommendation	No issues. Pathfinder will reduce schedule risk.	Pathfinder suggested to harden processes	Qualification model recommended to verify processes	Subscale pathfinder and full scale pathfinder recommended

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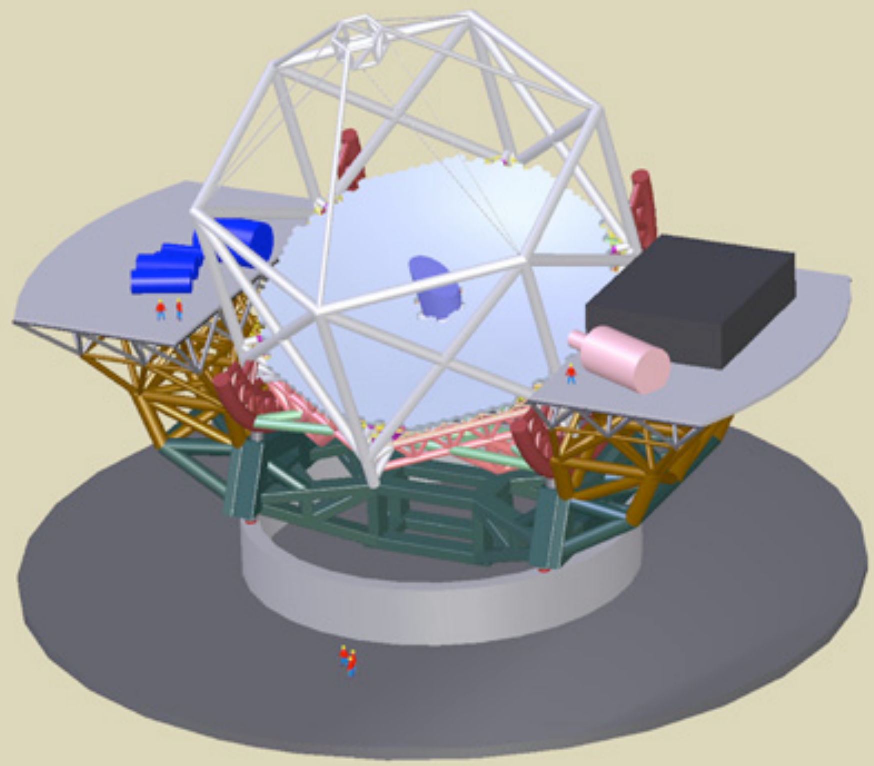
Large Ground Based Systems are also Planned to Augment Space Observations

- 30 meter systems use mirror segmentations similar to space systems (only larger and heavier & not deployed)
- Not driven by system mass or physical space constraints
  - Segments typically solids with no lightweighting which drives cost
- Mirror fabrication and processing can be manufactured in high quantity in production mode with investment in facilities



Thirty Meter Telescope concept

Typical ground based segment in optical test

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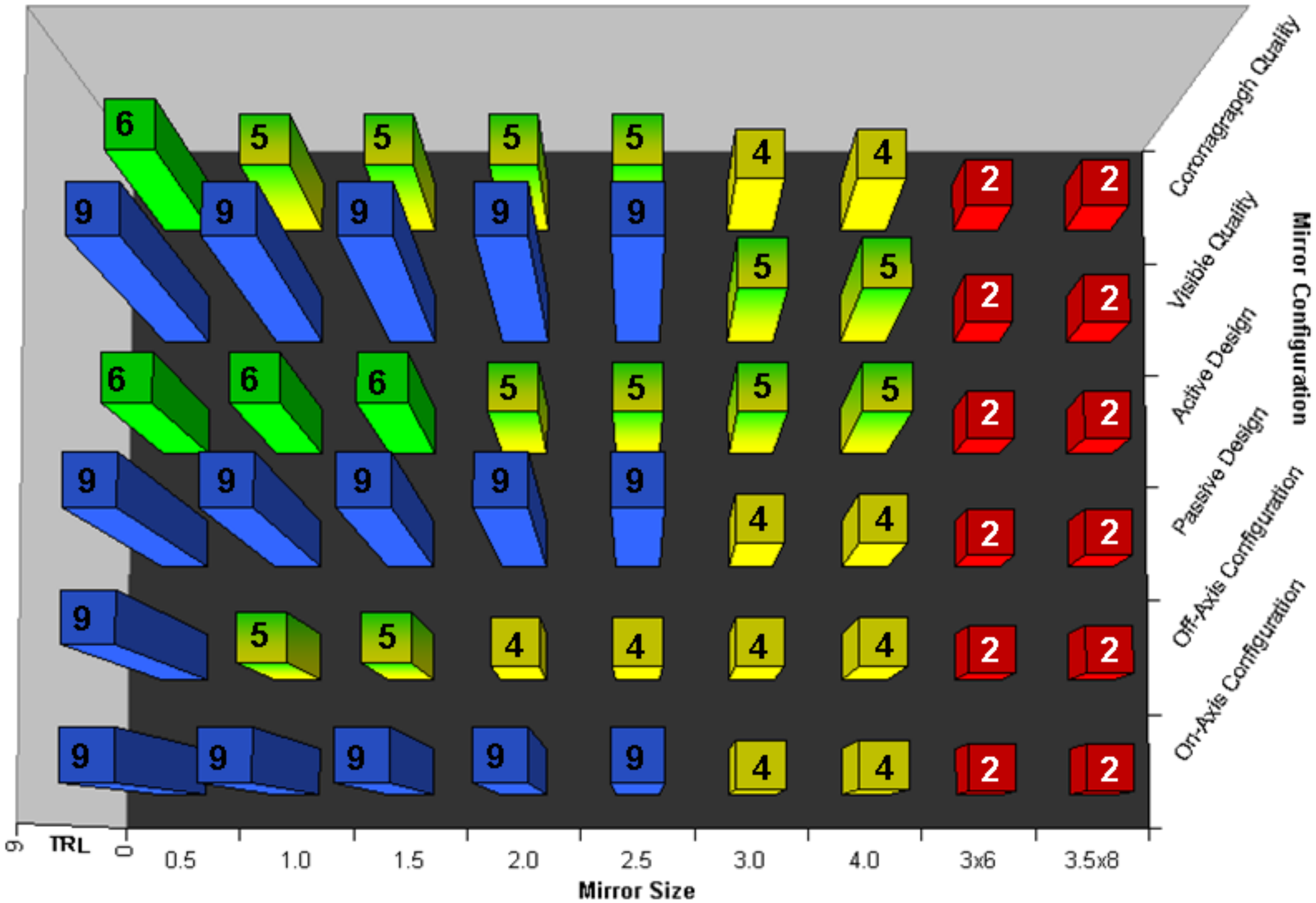
Mirror Technology Maturity Back-up Material

On-Axis Justification



- TRL 9
  - Based on Hubble Space Telescope, near UV quality primary mirrors up through 2.5 meters have been flown
- TRL 4
  - Large ground based mirrors are routinely manufactured, but are very heavy as compared to flight requirements.
  - Processes can be scaled but have not been demonstrated at 3-4m size.
- TRL 2
  - ITT Large Monolithic Mirror (LMM) NASA Research Announcement (NRA) study showed proof of concept design for building very large space primary mirror

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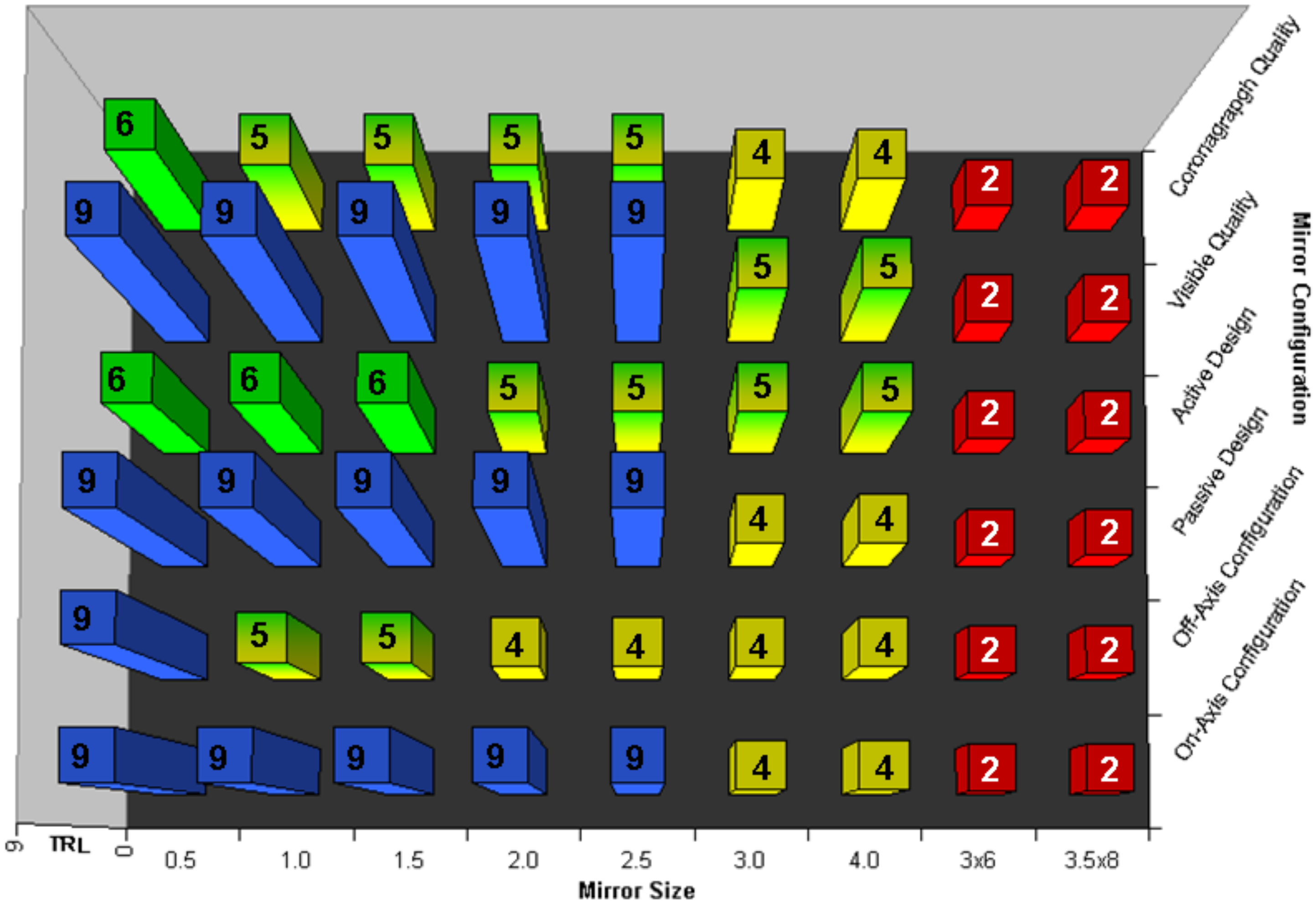
Off-Axis Justification



- TRL 9
  - Small off axis mirrors have been built and flown
- TRL 5
  - Advanced Mirror System Demonstrator (AMSD) has demonstrated lightweight off-axis capability up through 1.5m at IR quality.
- TRL 4
  - Large off-axis segments appear to be scalable.
  - Technology Demonstration Mirror (TDM) would show.
- TRL 2
  - ITT Large Monolithic Mirror (LMM) NRA study showed proof of concept design for building very large space primary mirror.

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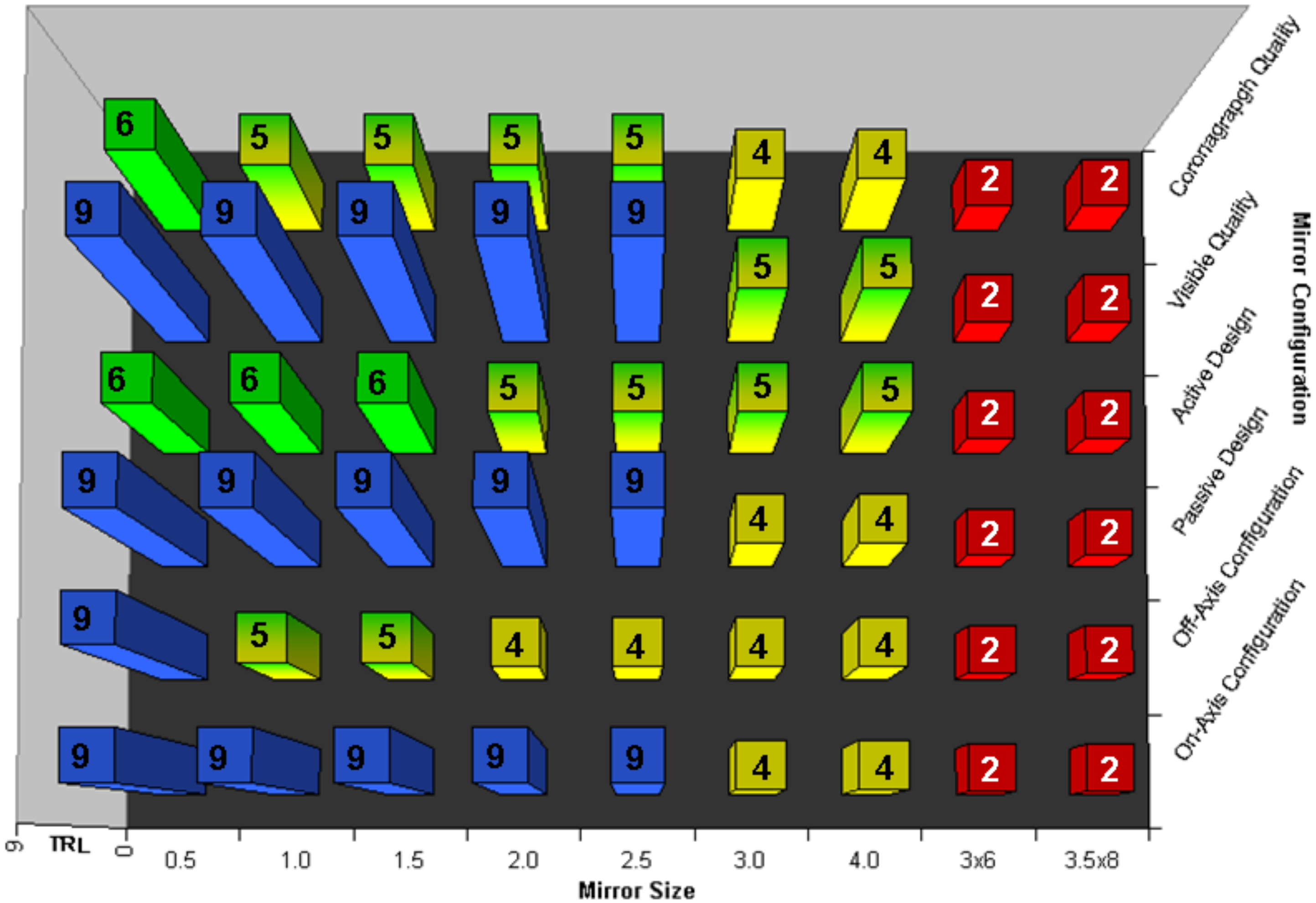
Passive Design Justification



- TRL 9
  - Based on Hubble Space Telescope, near UV quality, passive primary mirrors up through 2.5 meters have been flown
- TRL 4
  - Large ground based mirrors are routinely manufactured, but are very heavy as compared to flight requirements.
  - Processes can be scaled but have not been demonstrated at 3-4m size.
- TRL 2
  - ITT Large Monolithic Mirror (LMM) NRA study showed proof of concept design for building very large space primary mirror

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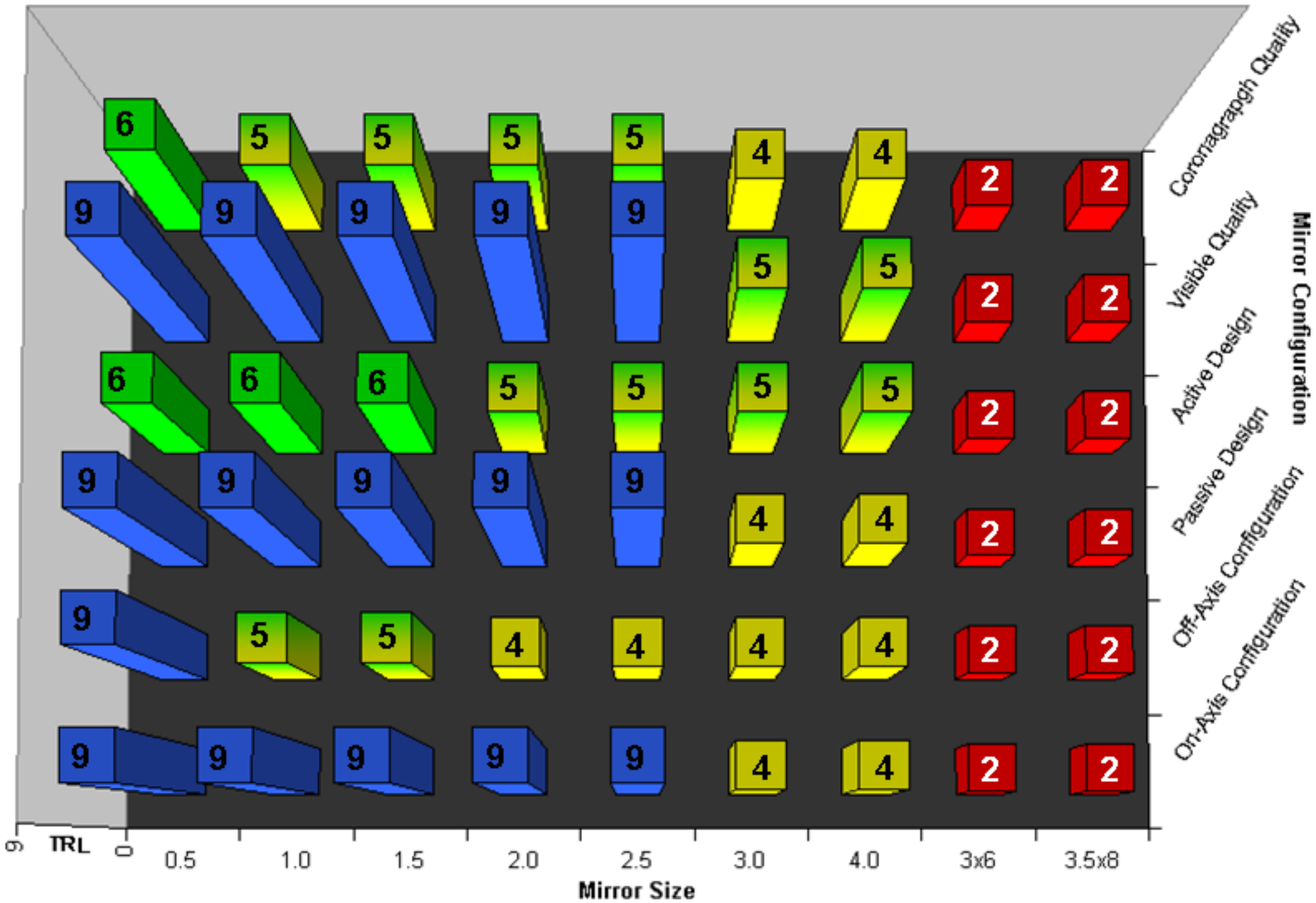
Active Design Justification



- TRL 6
  - Advanced Mirror System Demonstrator (AMSD) has demonstrated lightweight active off-axis capability up through 1.5m.
- TRL 4
  - Large ground based active mirrors are routinely manufactured. These systems are not flight qualifiable, but demonstrate reasonable feasibility.
- TRL 2
  - ITT Large Monolithic Mirror (LMM) NRA study showed proof of concept design for building very large active primary mirror.

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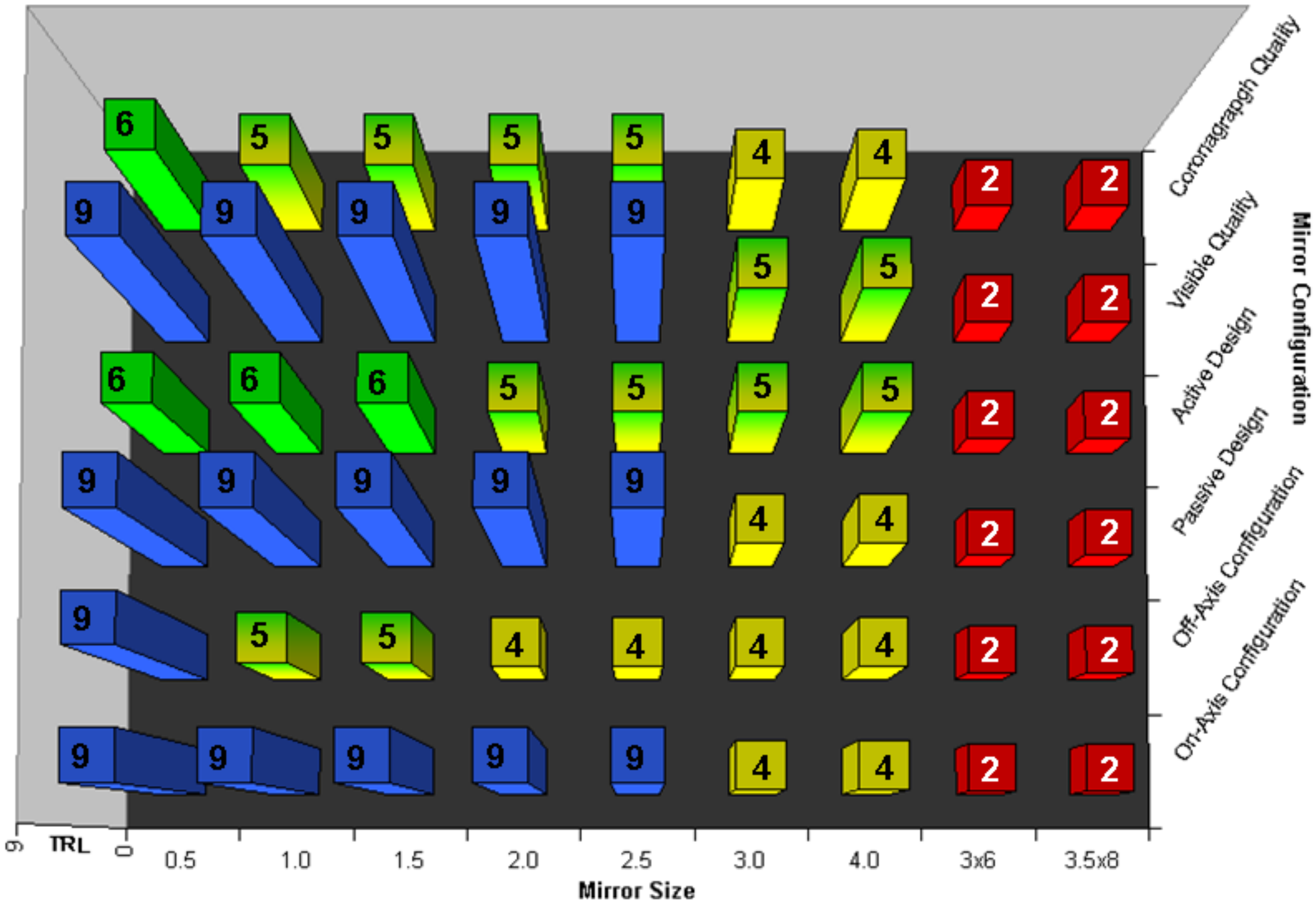
Visible Quality Justification



- TRL 9
  - Based on Hubble Space Telescope, near UV quality primary mirrors up through 2.5 meters have been flown
- TRL 4
  - Large ground based mirrors are routinely manufactured, but are very heavy as compared to flight requirements.
  - Processes can be scaled but have not been demonstrated at 3-4m size.
- TRL 2
  - ITT Large Monolithic Mirror (LMM) NRA study showed proof of concept design for building very large space primary mirror

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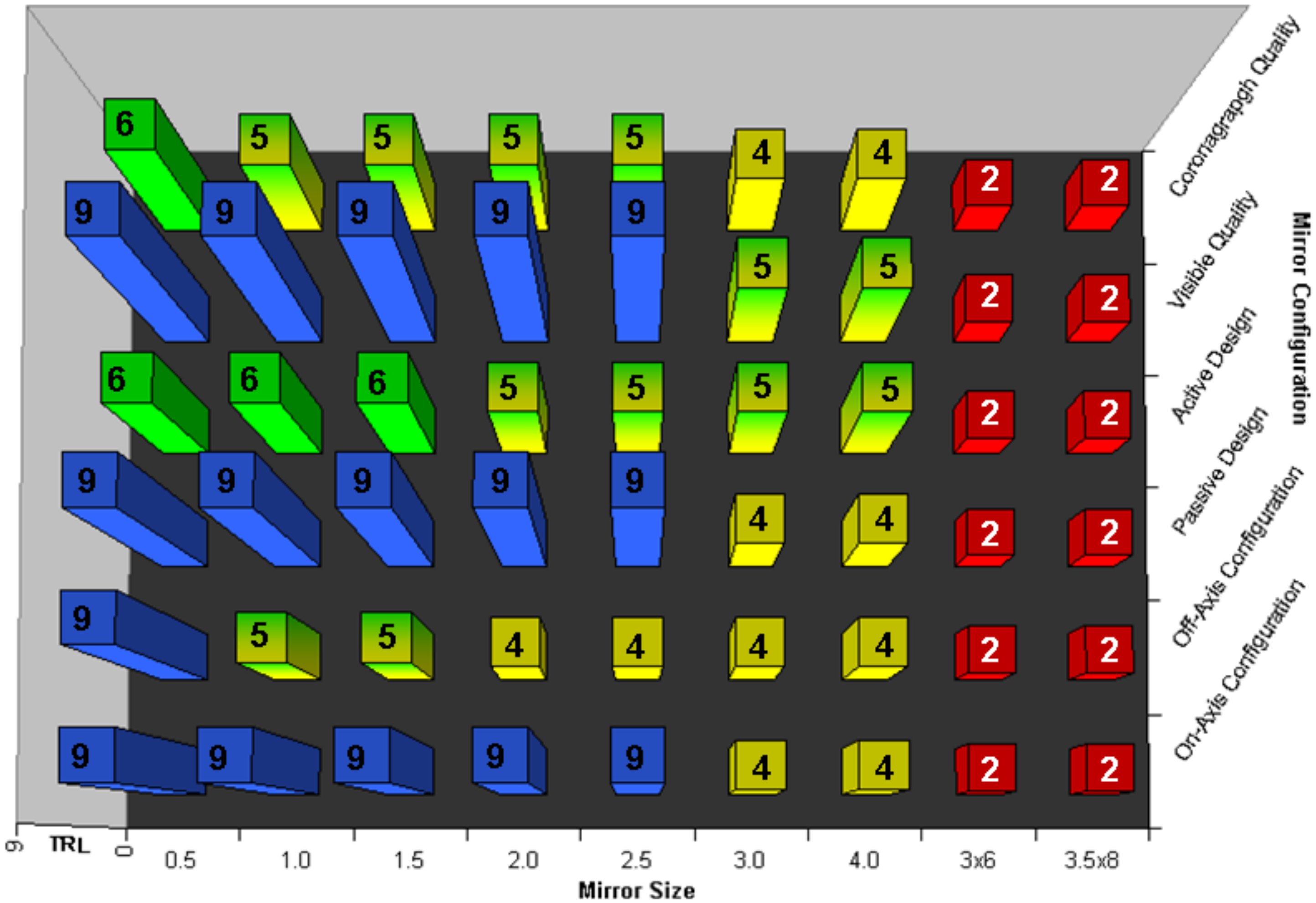
Coronagraphic Quality Justification



- TRL 9
  - Small very high quality optics have been flown.
- TRL 4/5
  - Large high quality optics appear to be manufacturable based on Hubble Space Telescope near UV quality mirror.
  - Demonstrate at scale would be required
- TRL 2
  - ITT Large Monolithic Mirror (LMM) NRA study showed proof of concept design for building very large space primary mirror

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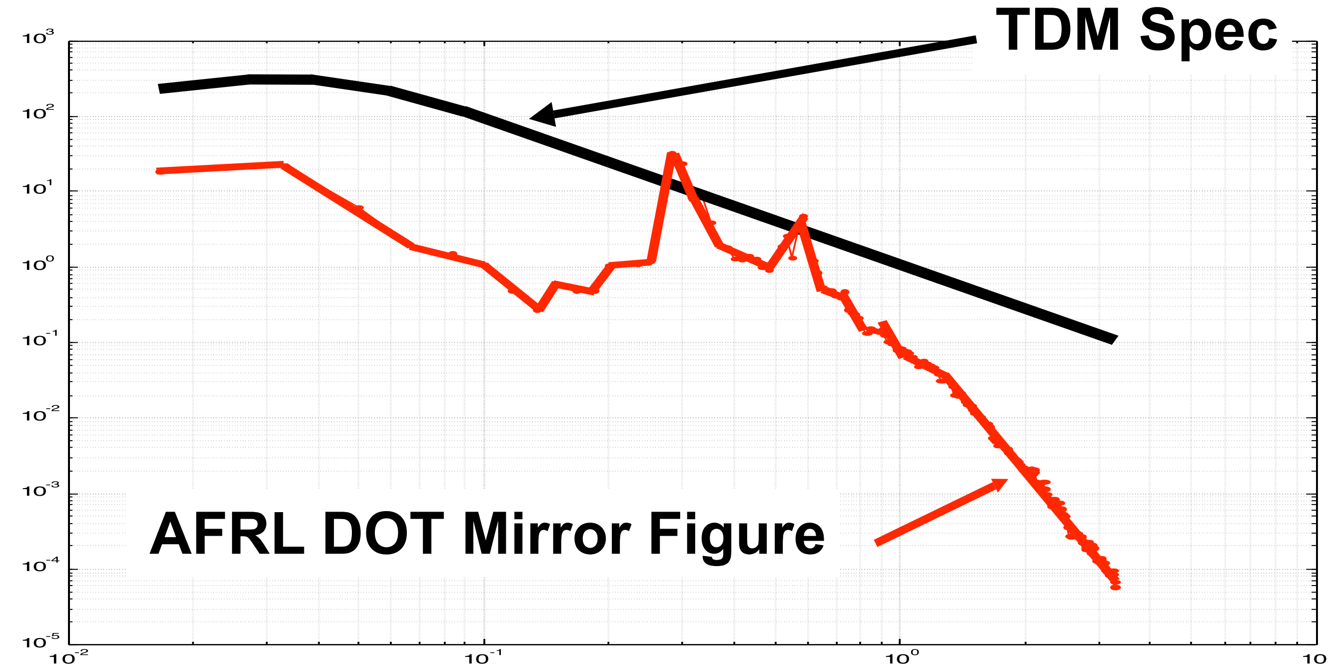
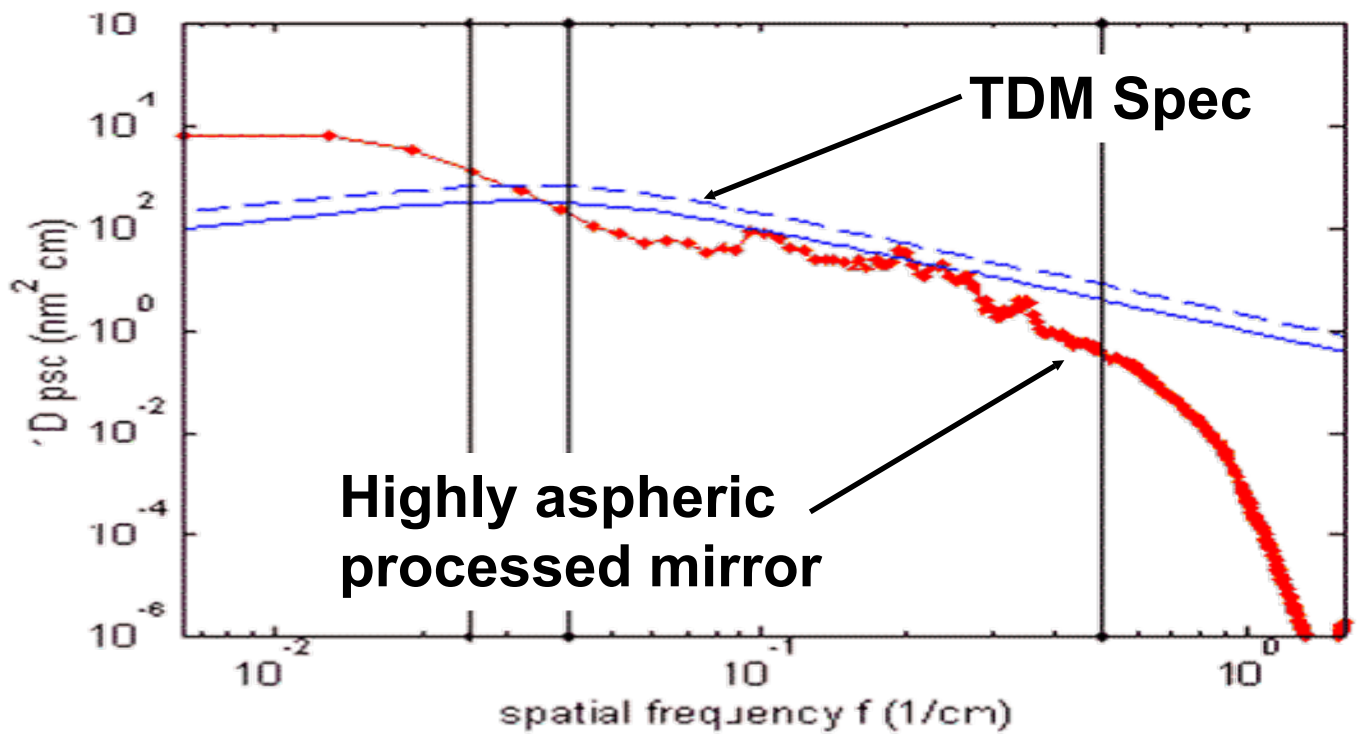
Mirror Quality

Processing Capability of Lightweight Mirrors

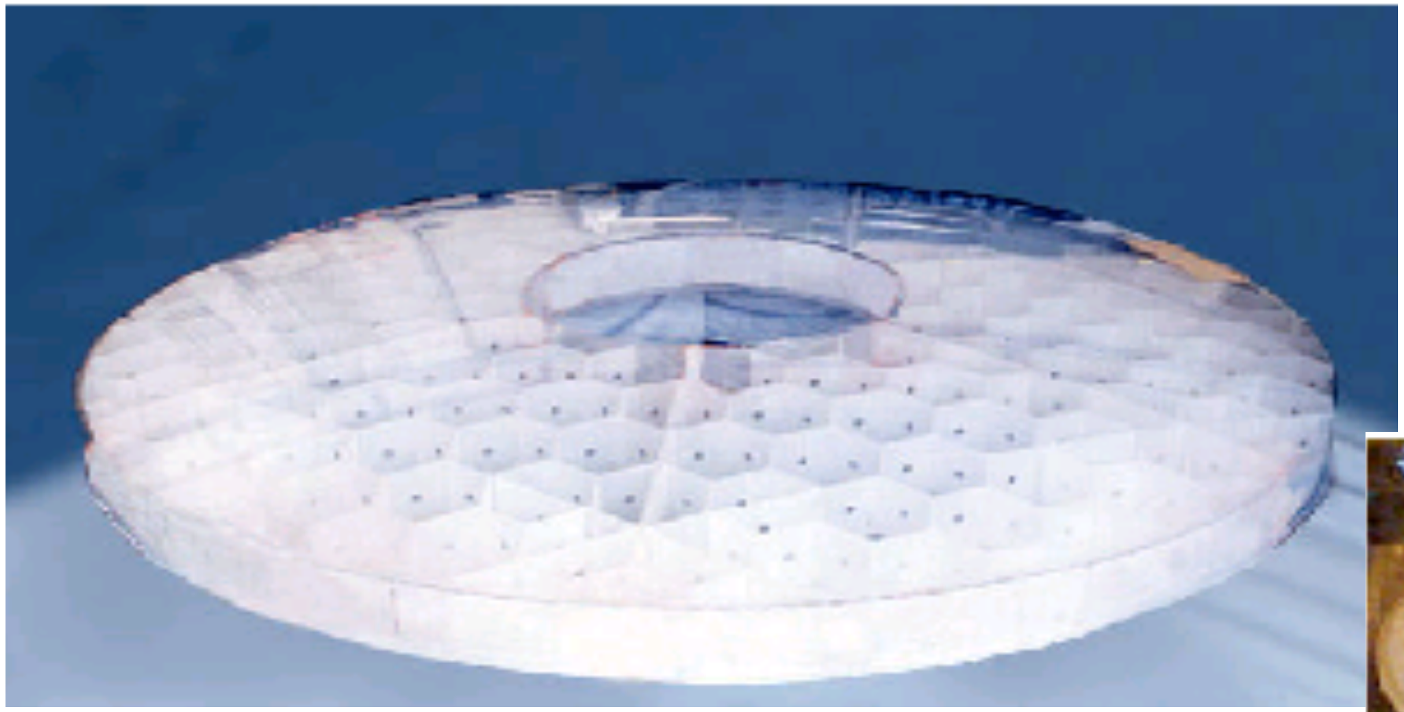
- Lightweight mirrors have been processed that approach coronagraphic quality
- If required, a qualification program would be needed to assure that the quality aspects of the mirrors in the flight configuration could be met





Ultra Lightweight 2m class Passive Primary Mirror Technology has been Demonstrated

- Abrasive waterjet lightweight segmented core reduces risk
- Pocket milled facesheets reduces weight to about 1/3 the areal density of HST with comparable stiffness
- Low Temperature Fusion (LTF) process eliminates the effects of Frit-bonding
- Directly scalable to 4m size



Advanced Technology Testbed (ATT) 2.4-meter Primary Mirror

ATT Pocket Milled Facesheet

Thermal

Thermal Analysis Accuracy / Development

- Sub-milliKelvin thermal analysis accuracy is achievable using currently available codes and computational capability
  - Factors that drive the accuracy of numerical solutions are incorporated in commercially available codes to allow trading accuracy against model size and computation time. With 64-bit processors, machine limitations are not an issue.
  - Data mapping between thermal and structural models has been automated
  - Modeling tools are available to deal with features such as anisotropy and spectral optical properties (rather than just “solar” and “infrared”)
  - Given sufficient need, codes can be extended to accommodate measured BRDF (specular and diffuse reflection models are limiting cases, not real reflection distributions)
- There is sufficient understanding of thermal analysis to evaluate mechanisms, check assumptions, identify uncertainties, and develop schemes for accommodating these in an end-to-end system model.
  - Effects of features and phenomena that are normally neglected in spacecraft applications, e.g. geometrical details, work done by thermal expansion, changes in composite properties due to aging, etc., can be evaluated and included
  - Material properties measurement accuracy is limited, but measurement uncertainties are readily addressed, even though the problem of assessing these uncertainties grows rapidly when considering not only the property measurement error but also the many possible ways that such errors can be distributed throughout a complex system
- Greatest risk is in managing the size of the end-to-end manufacturing and modeling task.
- Development tests for manufacturing rework.

Vibration Isolation Systems

- Disturbance Free payload
- Two-stage Isolation

Disturbance-Free Payload (DFP) Technology Summary

Lockheed Martin Space Systems Co.
May 2008
Nelson Pedreiro

Introduction & Background

Additional Information

- **Advanced system and control architecture for stringent stability requirements**
  - Provides precision payload control and isolation from spacecraft disturbances
  - Provides payload thermal isolation from spacecraft
  - Modular and compact spacecraft/payload interface
  - Mature sensor and actuator technologies (low risk, low cost)
- **Mission impact**
  - Increased overall mission efficiency (increase in observation time)
  - Increased performance margins (lower risk)
  - Relaxed requirements on spacecraft allowing reduced testing (lower risk, cost & schedule)
- **Robust architecture**
  - Payloads isolated from all spacecraft disturbances
  - Simple, well defined payload-spacecraft interface
  - Software controlled interface allows change to accommodate unforeseen effects in-orbit

Vibration isolation

Down to zero frequency

Not limited by sensor characteristics

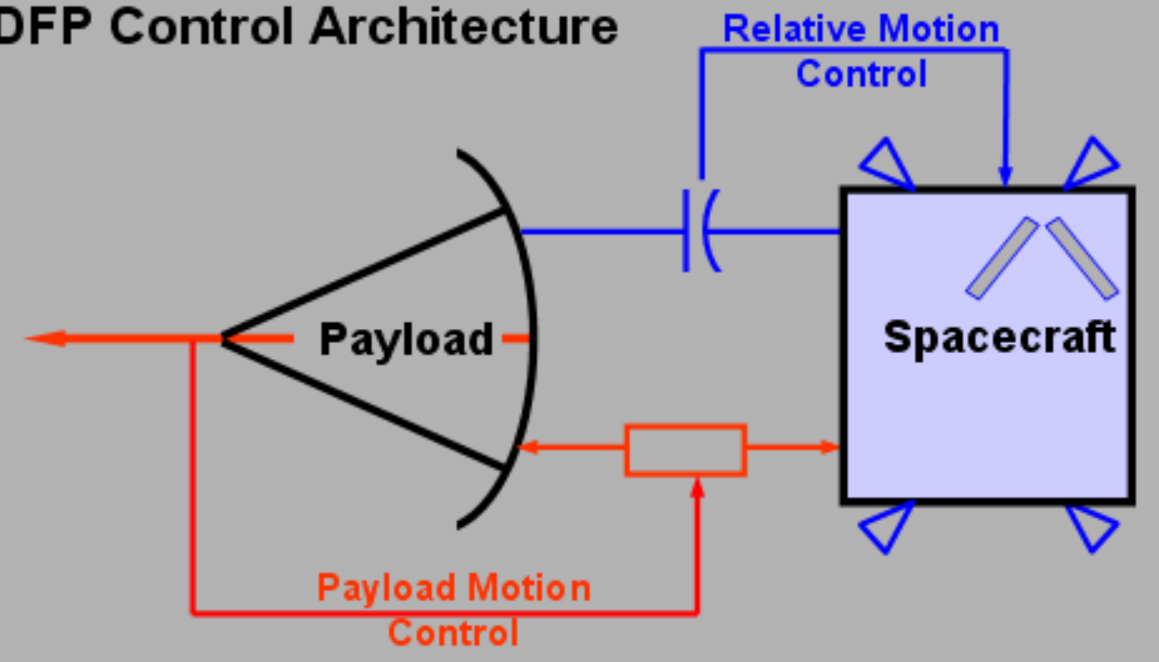
Thermal isolation

Payload thermal stability robust to spacecraft environment and loads

Mechanical Isolation

Payload opto-mechanical stability not affected by spacecraft and interface

DFP Control Architecture



DFP Technology Maturity

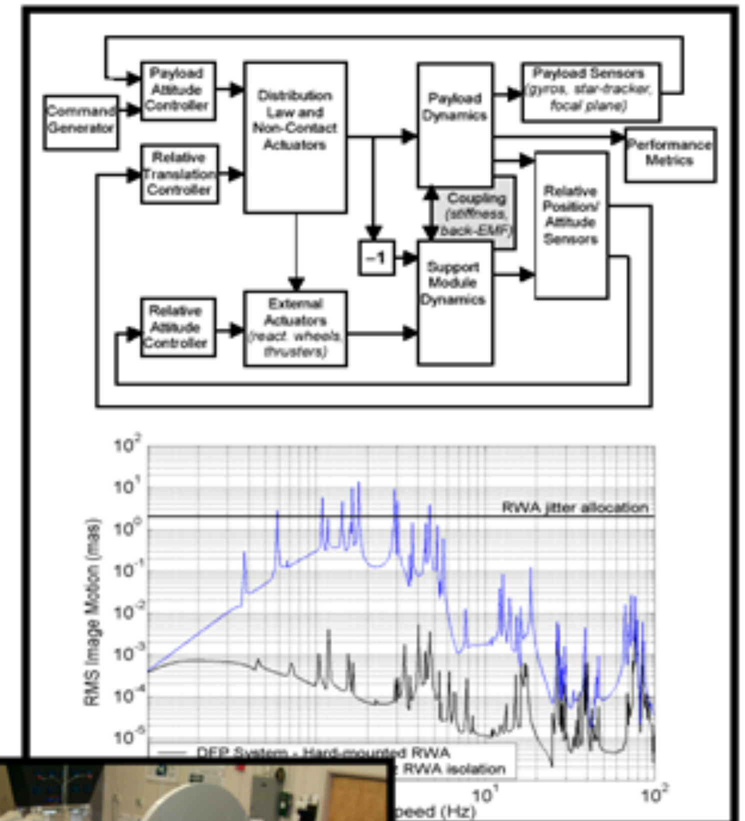
Additional Information

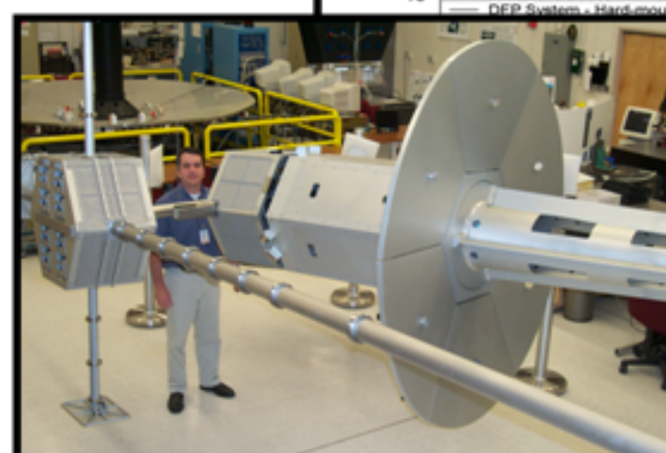
- **Current maturity between TRL 5 and 6**
  - DFP system level demonstrations completed in the laboratory
  - Component testing
  - On-orbit performance demonstrated through high-fidelity simulations

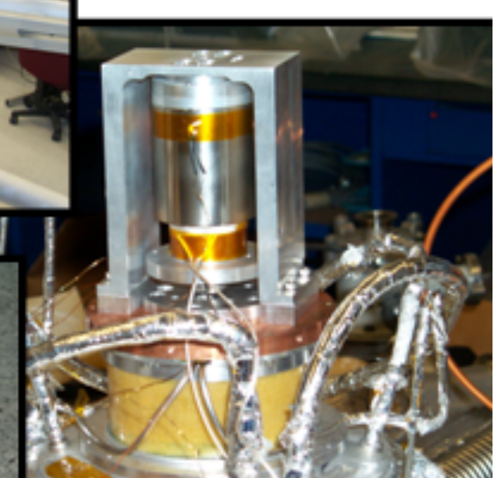
- **High-fidelity modeling and analysis tool in place**
  - Control system analysis and design
  - Frequency domain analysis tool
  - High-fidelity time-domain simulation
  - Applied to various systems: NGST, TPF-I, TPF-C, other

- **System-level testbed in-place**
  - Validate and anchor models
  - Can be tailored for early risk mitigation for specific programs, e.g. software development

TRL between 5 and 6





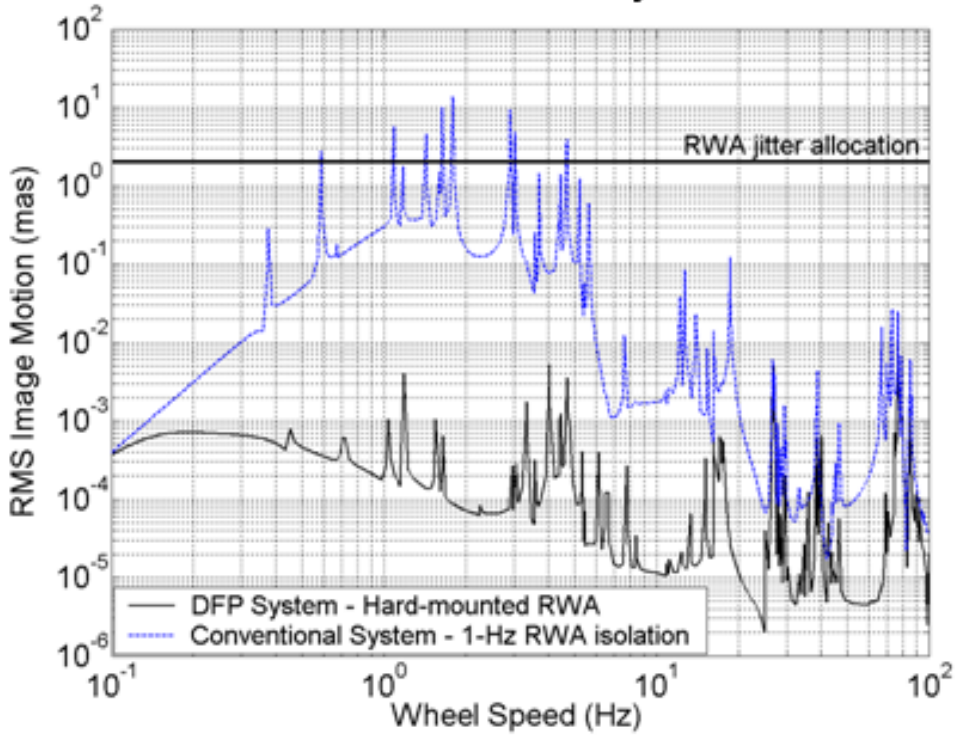


Performance

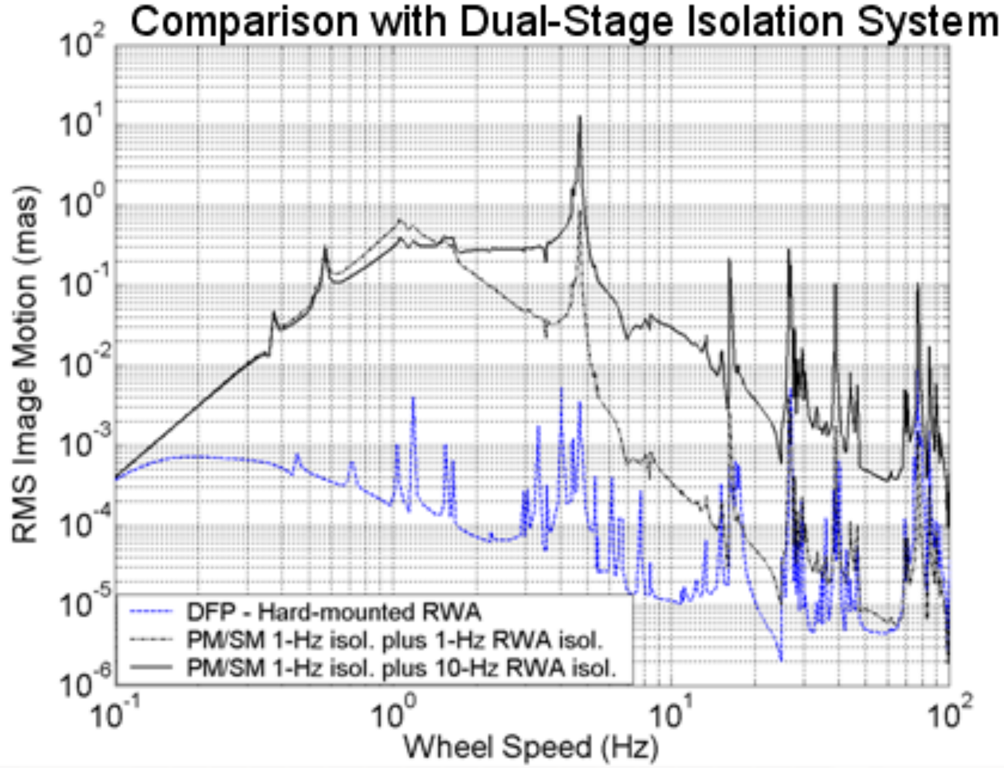
Additional Information

- **Hardware demonstration of 68-dB broadband isolation (1 to 100 Hz)**
  - System Level (DFP-3D) testbed
- **Demonstration of real-time control algorithms**
  - System Level (DFP-3D) testbed
- **Hardware demonstration of slewing and momentum dumping**
  - System level testbeds
  - Functionality and performance
- **High-fidelity model and simulation predict over two orders of magnitude isolation and pointing stabilility compared to state-of-the-art reaction isolation/pointing systems**
- **Demonstrated approach for minimum performance impact due to cable harness between payload and spacecraft**
- **Improved thermal isolation between payload and spacecraft demonstrated through analysis**

Comparison with 1-Hz Reaction Wheel Isolation System



Comparison with Dual-Stage Isolation System



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  - Lockheed Martin Proprietary
  - Over 75 technical reports covering dynamics model and simulations, systems engineering, requirements flow-down, testbed and hardware design, component and subsystem characterization, integration and testing, control system design and implementation, and system reliability and performance.
  - Detailed description of capabilities: analysis & hardware demonstrations
  - Contact:

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Coatings, Dichroics and Beam Splitters Technology

Detector Technology